

ISL6745ALEVAL3Z

TRIAC Dimmer Compatible High Brightness White LED Driver

AN1487
Rev 0.00
July 28, 2009

Abstract

The ISL6745ALEVAL3Z is a low cost, high performance LED driver with power factor correction function, and is compatible with the widely used wall dimmers. It uses Intersil's voltage mode PWM controller ISL6745A to operate a SEPIC converter in discontinuous conduction mode (DCM). The design gives high flexibility on both the input side and output load. With the same circuit configuration, it works well with and without a triac dimmer. While connecting to any AC source from 50V to 140V without dimmer, it gives high power factor correction with high waveform factor of the input current. As it is powered through a phase controlled wall dimmer, the averaged rectified voltage varies as to the phase angle of the wall dimmer. The brightness of the LED is dimmed by changing the LED current, which is proportional to the averaged rectified voltage. This driver circuit can be used for various LED lighting applications. The number of LEDs in a string can be as many as 14, or as few as 4. Therefore, this design provides the luminaire manufacturers a high performance, low-cost solution for LED drivers compatible with the TRIAC phase-control dimmers.

Design Specifications

Configuration with Sinusoidal AC Source

- Input V_{AC} : 50V ~140V
- Typical Power Factor PF: 0.98
- Typical Efficiency η : 80%
- Output Current I_{LED} : 10mA ~ 670mA
- Output Voltage V_{OUT} : 10V ~ 46V
- Switching Frequency F_S : 100kHz
- Output Voltage Ripple V_{RPP} : 50mV_(P-P)

Configuration with Phase Controlled Triac Wall Dimmer

- Input V_{AC} : 80V~ 140V
- Efficiency η : 78%
- Output Current I_{LED} : 10mA ~ 670mA
- Output Voltage V_{OUT} : 10V ~ 46V
- Switching Frequency F_S : 100kHz
- Output Voltage Ripple V_{RPP} : 50mV_(P-P)

The System Block Diagram is shown in Figure 1, where the triac phase controlled dimmer chops the AC voltages, and the bridge rectifies it so the voltage applied to the SEPIC converter (L_1, L_2, C_2, Q_1, D) is rectified chopped AC voltage. The duty ratio of the SEPIC switch Q_1 is controlled by the voltage mode PWM controller ISL6745A. The modulation signal V_{ERR} is derived from the current control circuit integrating the difference between the measured current of the LED string ($K R_S I_{LED}$) and the reference current signal (V_x). The circuit is implemented with Intersil's high performance rail-to-rail op-amp EL5420. The reference signal (V_x) is derived from the rectified AC voltage over $C_1, |V_{AC}|$.

The top and bottom view of the evaluation board ISL6745ALEVAL3Z is shown in Figure 2. The detailed design procedure for a discontinuous conduction mode (DCM) SEPIC converter with power factor correction (PFC) is discussed in Application Note AN1411, available on Intersil's website.

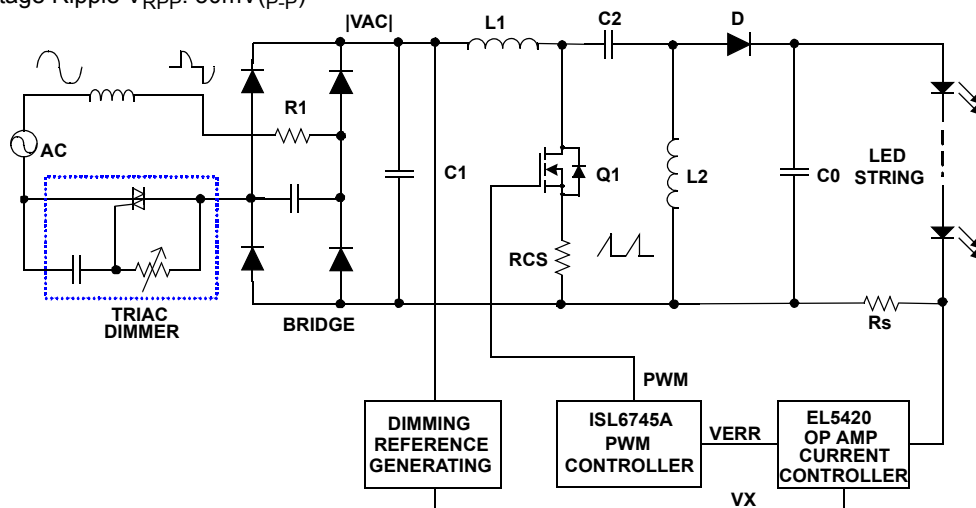


FIGURE 1. SYSTEM BLOCK DIAGRAM

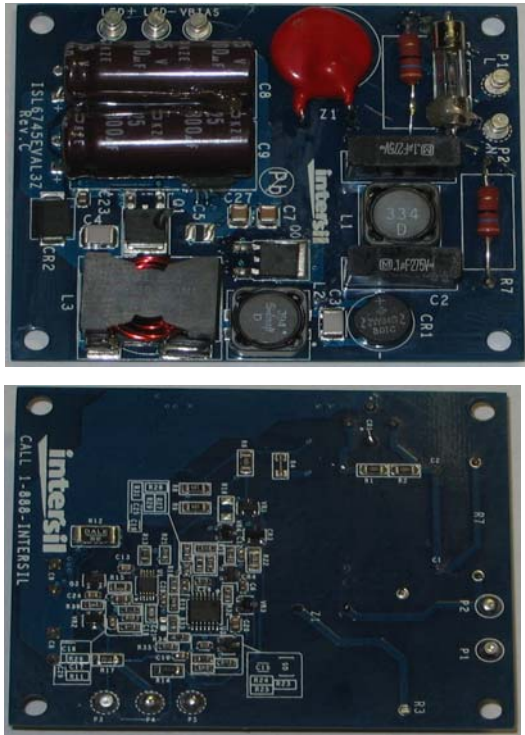


FIGURE 2. TOP AND BOTTOM VIEW OF LED DRIVER

Circuit Description

Unlike the active power factor correction converters, a voltage follower works in discontinuous conduction mode with comparatively constant duty ratio (D) within each utility cycle. There is no need for a PFC controller, or input voltage/current sense circuit. A simplified block diagram is shown in Figure 4. A typical waveform of the voltage after a triac dimmer is shown in Figure 3, where high dv/dt is noticed as the triac is turned on. A small capacitor C_1 is recommended here to filter out the switching noises. C_1 should be very small so that the voltage across it follows closely the rectified input voltage $|V_{AC}|$. An Electrolytic

capacitor is not suitable for this purpose, because of its high ESR and dielectric loss. Instead, a high frequency film capacitor such as metallized mylar or polypropylene should be used.

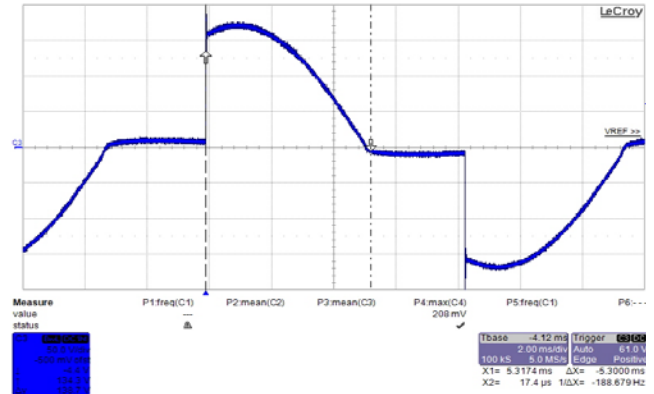


FIGURE 3. TYPICAL VOLTAGE AFTER THE TRIAC DIMMER

A damper resistor R_1 is needed to reduce the ringing effect because of the high dv/dt caused by the phase-angle dimming control of the triac. A minimum resistance should be used to ensure as low as possible power loss, while achieving normal dimming function. This resistor can be shorted if the driver is not triac dimmer controlled. L_1 and L_2 are selected so that the converter operates in DCM. The details of the design of the two inductors and capacitor C_2 can be found in Application Note AN1411.

One simple and low-cost solution for LED lamp brightness dimming is to control the LED current. It is assumed that the brightness of the LED lamp is linearly proportional to its current in normal conditions. Although the tune and color may change with operating current, the current based dimming method is acceptable for common LED luminaire applications. The current reference signal is in proportion to the averaged rectified voltage $|V_{AC}|$. The average voltage versus the phase angle α of triac dimmer is shown in Figure 5 for a commercial dimmer.

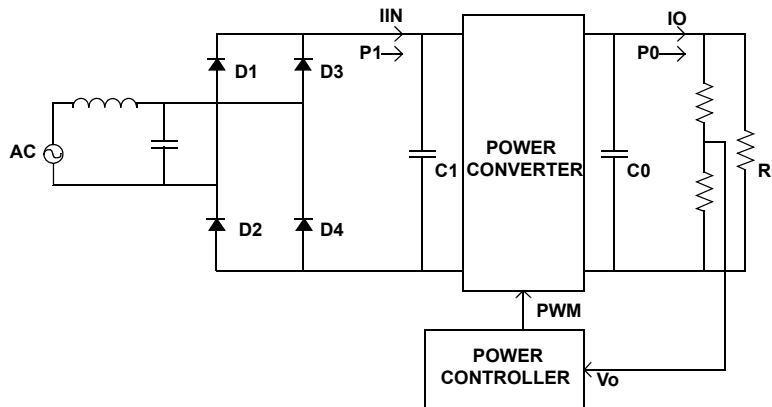


FIGURE 4. VOLTAGE FOLLOWER BLOCK DIAGRAM

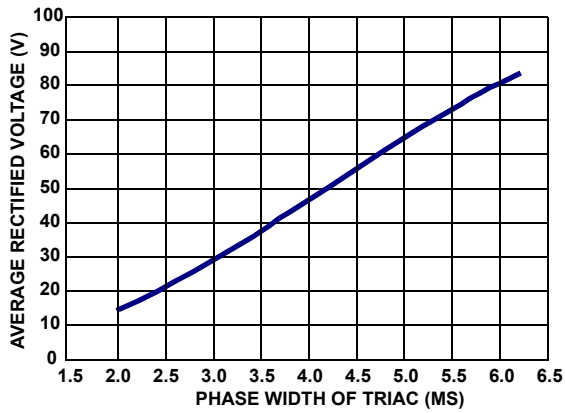


FIGURE 5. AVERAGE VOLTAGE vs ANGLE OF A TRIAC DIMMER

The schematic diagram of the current reference circuit is shown in Figure 6, where $|V_{AC}|$ is the rectified voltage after the rectifier. The high performance Op-Amp EL5420 clamps the current reference if the averaged input of U3A is beyond the bias voltage.

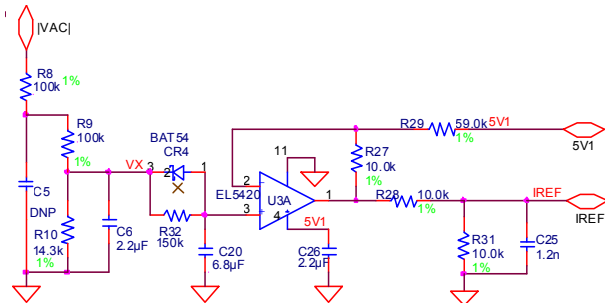


FIGURE 6. REFERENCE CIRCUIT

The LED current reference can be changed through R_{10} and R_{29} for applications with different rated operating current.

Figure 7 shows the LED current control circuit, where U4C provides 10 times of gain to reduce the power loss in the current sense resistor R_s . The integration circuit implemented with U3B eliminates any discrepancy between the reference (I_{REF}) and the LED current (I_{LED}). The time constant set by C_{19} and R_{33} should be large enough so that the second order harmonics will not appear in the control signal. A typical way is to set the time constant to 0.5 times of the utility frequency.

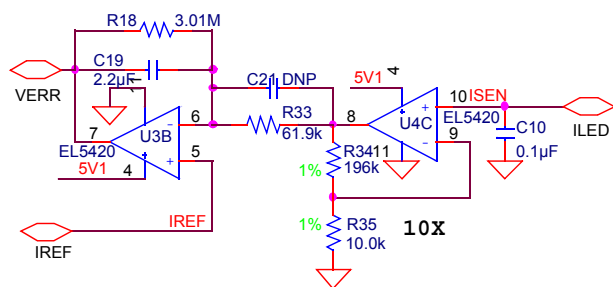


FIGURE 7. CURRENT CONTROL LOOP

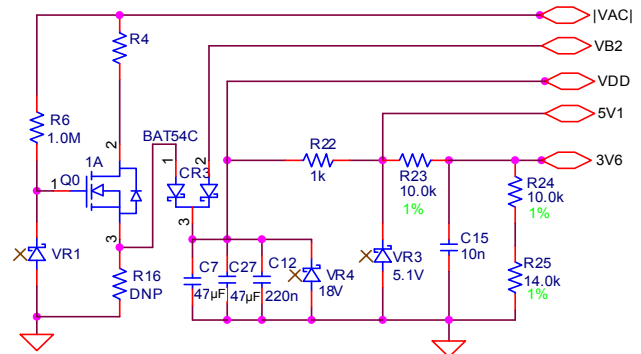


FIGURE 8. BIAS CIRCUIT

The bias circuit is shown in Figure 8 together with the reference voltages for the control circuit. At the beginning, the $|V_{AC}|$ increases so that the voltage at the gate of Q_0 is about 12V, Q_0 is turned on, and C_7 is charged up with $|V_{AC}|$ through R_4 . The ISL6745A starts to work as soon as the VDD is above its threshold. The output capacitor is charged up once the converter begins to work. The VB2 presents an alternative bias choice for the driver for high voltage applications. If it is connected to the 3rd of the LED strings, 3 times of p-n junction voltage presents when LED strings start conducting current. This will shut off the current path of Q_0 , CR_3 , and prevents the Q_0 from conducting current in normal operation conditions.

The following circuit in Figure 9 shows a soft-start circuit with overvoltage protection and delayed start-up circuit. The VR_2 , R_{39} , R_{15} set up the over voltage protection of the output voltage applied to LED strings. For an overvoltage of any reasons, the Q_3 will be turned on, and the SS charges will be discharged through R_{15} . In order to suppress the LED over-shot current during start-up, a delayed start-up circuit consisting of U4D and Q_5 is necessary. Only after SS voltage is beyond 3.6V, the Q_5 will be turned off, and V_x is presented in the reference generation circuit. This greatly reduces the over-shot of the LED strings during start-up.

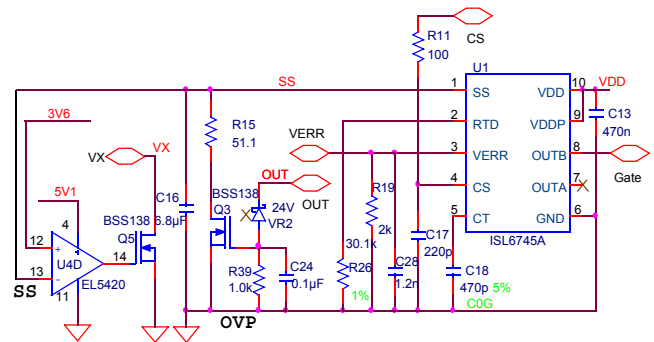


FIGURE 9. CONFIGURATION OF ISL6745A, SOFT-START-UP AND OVERVOLTAGE PROTECTION

The overall schematics of the driver and the associated BOM are presented in the last pages of this application note. The fixture of the PCB is a 2-layer board with dimensions 3.15 by 2.65 inches. Figures 10 and 11 show the top view

and bottom view of the PCB layouts. Gerber files for the ISL6745ALEVAL3Z board are available upon request.

The performance of the LED driver board will be evaluated with and without dimmer respectively in the next sessions for various operation conditions.

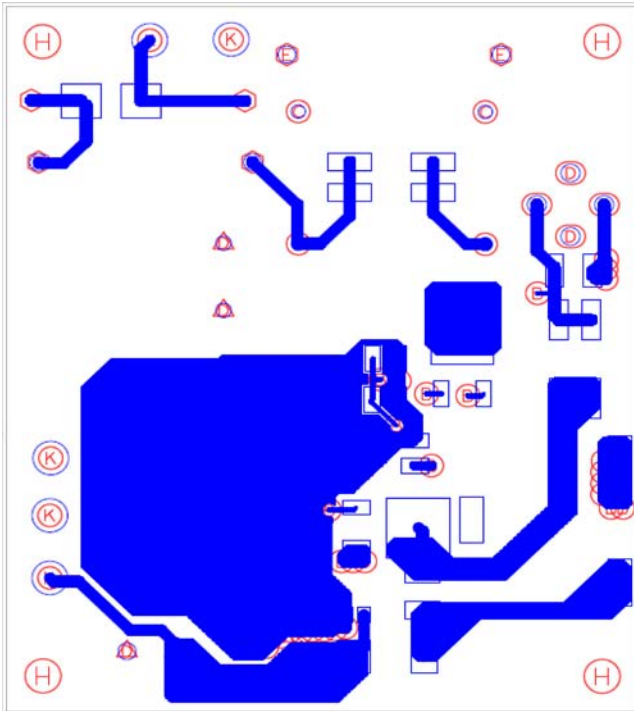


FIGURE 10. TOP VIEW OF THE PCB LAYOUT

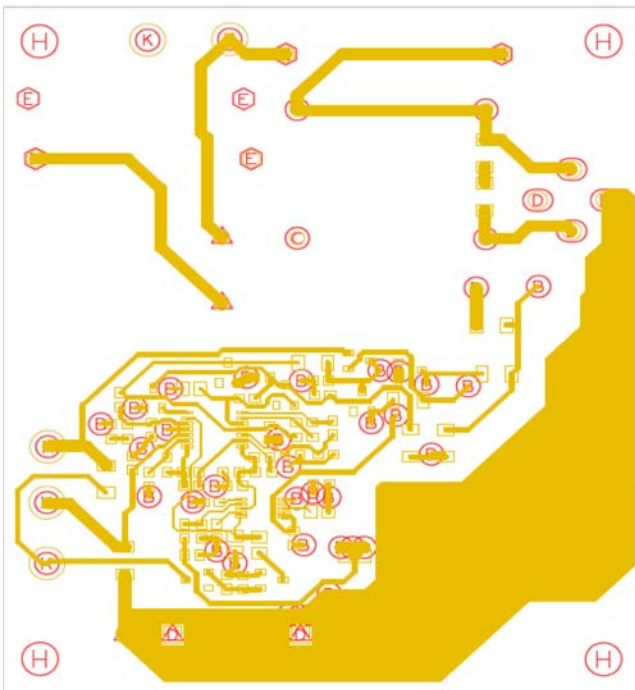


FIGURE 11. BOTTOM VIEW OF PCB LAYOUT

Performance Characteristics Without Dimmer

The schematics and BOM without dimmer are shown in the last pages of this document. Connect the P1 and P2 of the LED driver board to the AC power supply. A string of 6 Cree high power white LEDs are connected to the output terminal of the LED driver board. The efficiency of the driver is shown in Table 1. The operation waveforms are shown in Figures 12 to 18. Figures 12 to 15 show the rectified input voltage and current for different inputs. Channel 1 (yellow) shows the rectified input voltage (100V/DIV). Channel 4 (green) shows the input current (200mA/DIV). The input voltage and input current waveforms in Figure 16 shows the driver turning off within 2s. Figures 17 and 18 show the overshoot of the LED. Current is greatly reduced with the delayed start-up circuit.

TABLE 1. EFFICIENCY AND POWER FACTOR WITHOUT DIMMER

| VAD (RMS) (V) | I INPUT (mA) | POWER IN (W) | I LED (mA) | V/LED (V) | PF | EFF (%) |
|---------------|--------------|--------------|------------|-----------|--------|---------|
| 140.25 | 126 | 15.43 | 0.673 | 18.584 | 0.8720 | 81.06 |
| 130.20 | 132 | 15.49 | 0.673 | 18.581 | 0.8972 | 80.73 |
| 120.12 | 140 | 15.52 | 0.672 | 18.587 | 0.9212 | 80.48 |
| 110.11 | 149 | 15.53 | 0.672 | 18.584 | 0.9427 | 80.41 |
| 100.09 | 162 | 15.54 | 0.675 | 18.589 | 0.9585 | 80.74 |
| 90.08 | 176 | 15.51 | 0.671 | 18.584 | 0.9761 | 80.40 |
| 80.07 | 178 | 14.04 | 0.611 | 18.412 | 0.9811 | 80.13 |
| 70.06 | 170 | 11.79 | 0.521 | 18.167 | 0.9875 | 80.28 |
| 60.05 | 162 | 9.68 | 0.430 | 17.983 | 0.9899 | 79.88 |
| 50.04 | 151 | 7.55 | 0.338 | 17.738 | 0.9947 | 79.41 |
| 40.03 | 138 | 5.51 | 0.245 | 17.503 | 0.9974 | 77.83 |
| 30.02 | 116 | 3.48 | 0.152 | 17.085 | 0.9979 | 74.62 |
| 20.01 | 77 | 1.52 | 0.058 | 16.420 | 0.9956 | 62.66 |

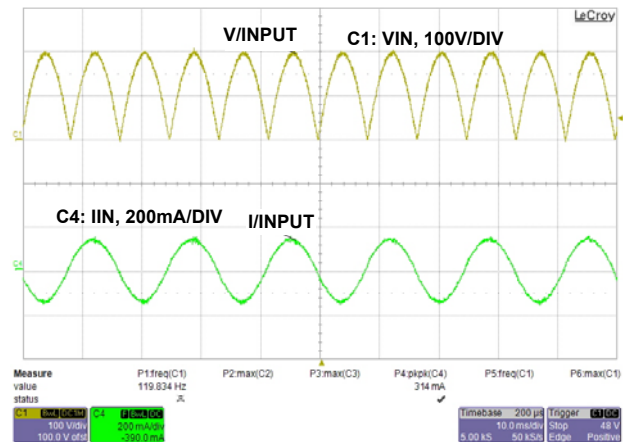


FIGURE 12. INPUT VOLTAGE AND CURRENT @ 140V

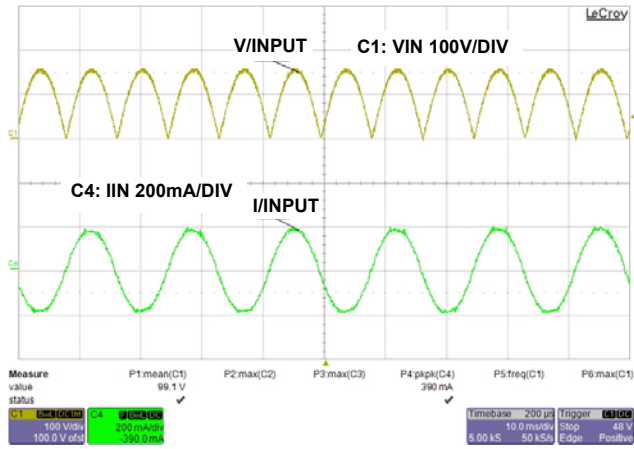


FIGURE 13. INPUT VOLTAGE AND CURRENT @ 110V

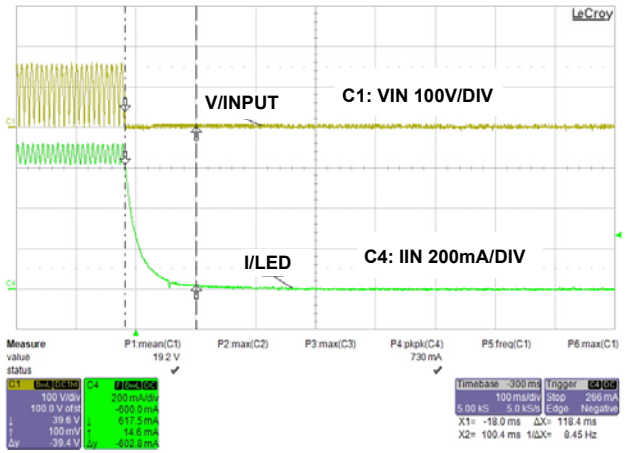


FIGURE 16. FAST TURN-OFF @ 110V

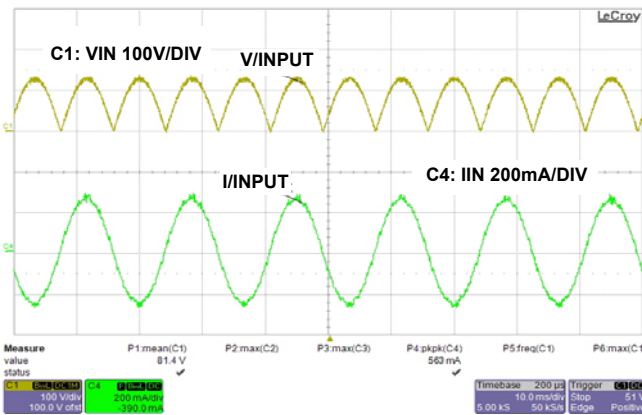


FIGURE 14. INPUT VOLTAGE AND CURRENT @ 90V

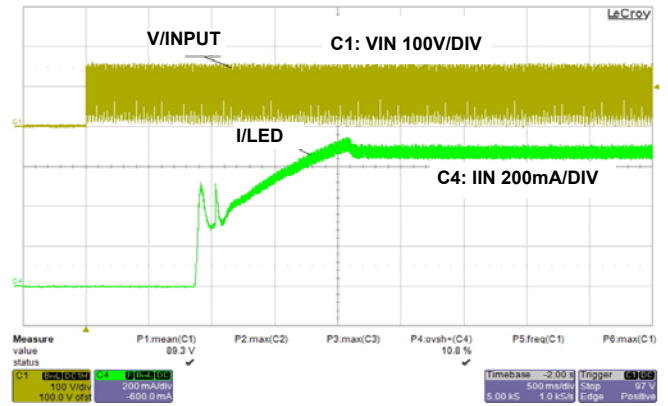


FIGURE 17. TURN ON OVER-SHOT @ 110V

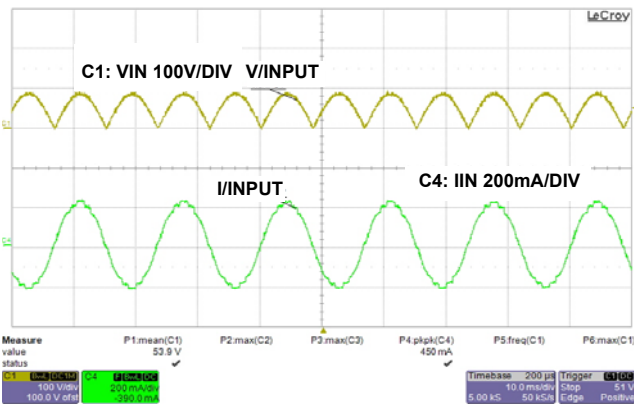


FIGURE 15. INPUT VOLTAGE AND CURRENT @ 60V

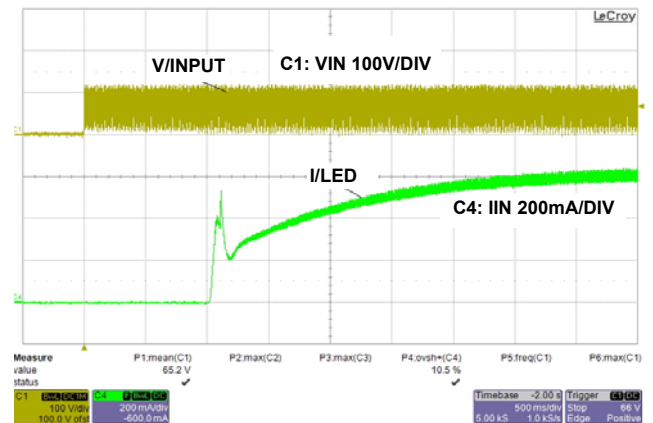


FIGURE 18. TURN ON OVER-SHOT @ 80V

Typical Performance Characteristics with Dimmer

See “Schematic With/Without Triac Dimming Compatible” on page 8, tables 5 and 6. Connect the P1 and P2 of the LED driver board to the AC power supply. A string of 6 Cree high power white LEDs is connected to the output terminal of the LED driver board. The efficiency of the driver is shown in Table 2 for 110V input.

The operation waveforms are shown in Figures 19 to 24, respectively. Figures 19 to 22 show the rectified input voltage and current for different inputs. Figures 23 and 24 show the overshoot of the LED. Current is greatly reduced with the delayed start-up circuit.

TABLE 2. EFFICIENCY AND POWER FACTOR WITH DIMMER

| PHASE WIDTH (ms) | POWER INPUT (W) | I LED (mA) | V LED (V) | PF | EFF (%) |
|------------------|-----------------|------------|-----------|------|---------|
| 7.436 | 16.99 | 0.671 | 18.332 | 0.99 | 72.40 |
| 5.844 | 15.064 | 0.600 | 18.011 | 0.94 | 71.74 |
| 5.212 | 12.428 | 0.501 | 17.777 | 0.87 | 71.66 |
| 4.512 | 10.212 | 0.401 | 17.608 | 0.75 | 69.14 |
| 3.984 | 7.758 | 0.300 | 17.443 | 0.64 | 67.45 |
| 3.404 | 5.100 | 0.200 | 17.182 | 0.51 | 67.38 |
| 2.588 | 2.629 | 0.093 | 16.724 | 0.35 | 59.16 |
| 1.808 | 0.756 | 0.015 | 15.851 | 0.17 | 31.45 |

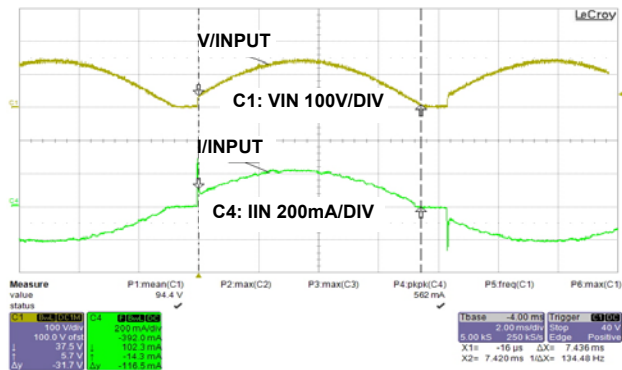


FIGURE 19. PHASE CONTROLLED VOLTAGE AND INPUT CURRENT

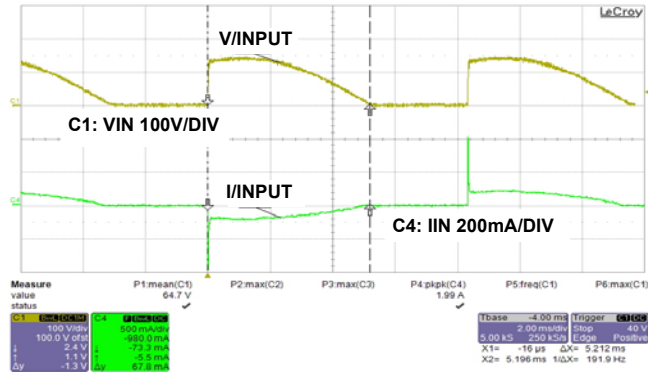


FIGURE 20. PHASE CONTROLLED VOLTAGE AND INPUT CURRENT

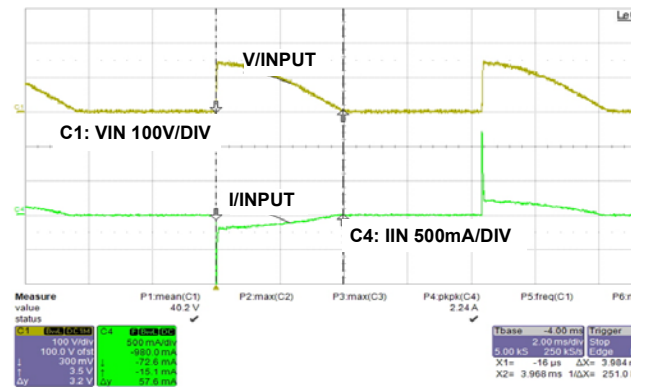


FIGURE 21. PHASE CONTROLLED VOLTAGE AND INPUT CURRENT

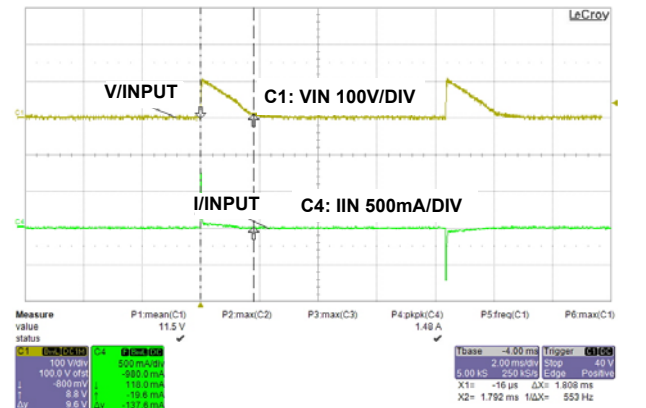


FIGURE 22. PHASE CONTROLLED VOLTAGE AND INPUT CURRENT

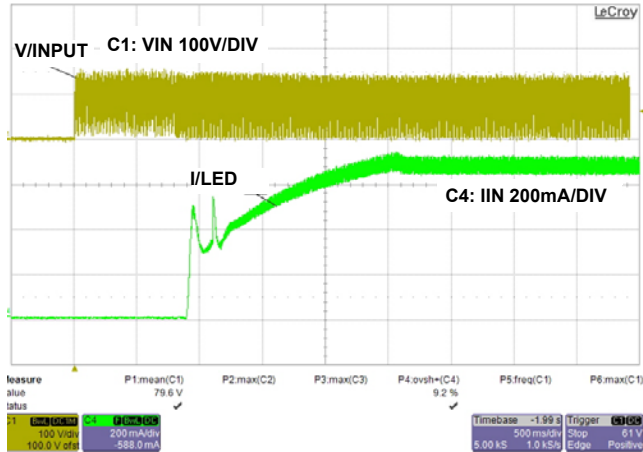


FIGURE 23. OVERSHOT OF LED CURRENT (672mA, 9%)

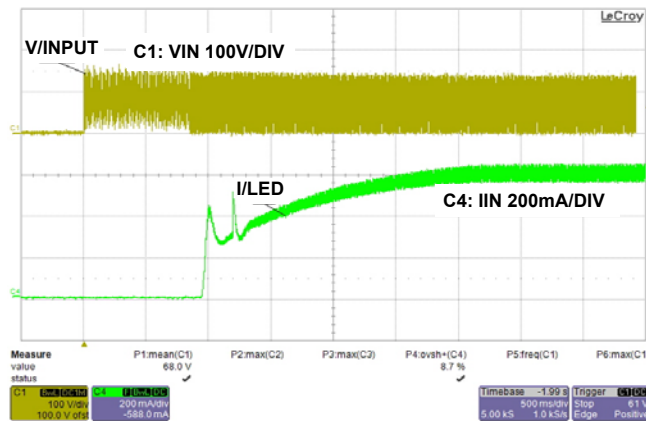


FIGURE 24. OVERSHOT OF LED CURRENT (600mA, 8%)

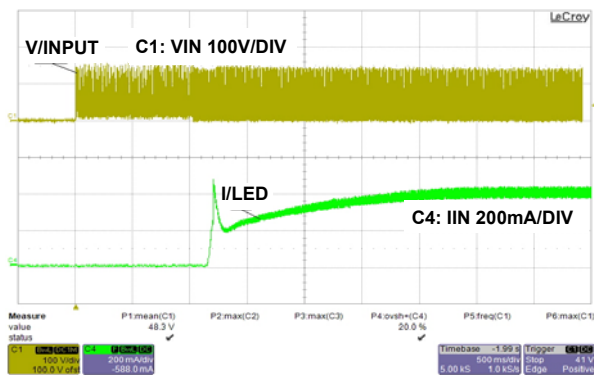


FIGURE 25. OVERSHOT OF LED CURRENT (400mA, 22%)

Thermal Performance Characteristics

The temperature test of the board, and critical components of the driver with/without dimmer is shown in Tables 3 and 4 for 110V input full load conditions.

TABLE 3. CIRCUIT WORK WITHOUT DIMMER FOR 6 LEDS

| COMP | T = +85°C | T = +25°C | T = 0°C | T = -40°C |
|------|-----------|-----------|---------|-----------|
| Q1 | 98 | 36 | 11 | -30 |
| L1 | 88 | 26 | 3 | -35 |
| L2 | 90 | 33 | 3 | -34 |
| L3 | 88 | 26 | 3 | -37 |
| C4 | 88 | 26 | 3 | -37 |
| R4 | 86 | 26 | 0 | -37 |
| R12 | 97 | 37 | 13 | -26 |
| Q0 | 89 | 33 | 3 | -34 |
| CR2 | 109 | 49 | 10 | -24 |
| C8 | 88 | 29 | 3 | -37 |

TABLE 4. CIRCUIT WORK WITHOUT DIMMER FOR 6 LEDS

| COMP | T = +85°C | T = +25°C | T = 0°C | T = -40°C |
|------|-----------|-----------|---------|-----------|
| Q1 | 100 | 38 | 13 | -28 |
| L1 | 88 | 30 | 2 | -37 |
| L2 | 88 | 30 | 2 | -37 |
| L3 | 88 | 28 | 2 | -37 |
| C4 | 88 | 28 | 2 | -37 |
| R3 | 126 | 84 | 50 | -18 |
| R12 | 95 | 37 | 10 | -25 |
| Q0 | 90 | 30 | 5 | -34 |
| CR2 | 92 | 48 | 7 | -32 |
| C8 | 88 | 28 | 2 | -37 |

References

1. ISL6745A datasheet, Intersil Corporation
2. ISL5420 datasheet, Intersil Corporation
3. ISL6745EVAL2Z Offline High Brightness White LED Driver With High Power Factor for Universal Input, Intersil Corporation application note: AN1411
4. Z. Ye, et al, "Design Considerations of a High Power Factor SEPIC Converter for High Brightness White LED Lighting Applications," IEEE PESC conference record, 2008, June 2008, Greece, pp 2657- 2663.

Schematic With/Without Triac Dimming Compatible

TABLE 5. ISL6745ALEVAL3Z NON-ISOLATED LED ADAPTOR WITHOUT TRIAC DIMMING

| NO. | QTY. | REFERENCE | VALUE | VALUE NO. | PACKAGE | TOL | VOLTAGE (V) | VENDOR | PART NO. |
|-----|------|--------------------|----------------|-----------|------------------|---------|-------------|-----------|--------------------|
| 1 | 1 | CR1 | 2A | | BRIDGE RECTIFIER | | 400 | DIODES | 2W04G |
| 2 | 1 | CR2 | 3A | | SMC | | 600 | DIODES | RS3J-E3 |
| 3 | 1 | CR3 | BAT54C | | SOT23 | | | DIODES | |
| 4 | 1 | CR4 | BAT54 | | SOT23 | | | DIODES | |
| 5 | 2 | C1, C2 | 0.1 μ F | | X2-CAP | | 250 | PANASONIC | ECQU2A 104ML |
| 6 | 1 | C3 | 22nF | | SM1812 | | 250 | TDK | C453C0G2E223J |
| 7 | 1 | C4 | 47nF | | SM1812 | | 250 | TDK | C453C0G2E223J |
| 8 | 1 | C5 | DNP | | SM1210 | | 100 | MURATA | |
| 9 | 1 | C6 | 2.2 μ F | | SM0603 | | | MURATA | GRM31CR71H225K |
| 10 | 2 | C7, C27 | 47 μ F | | SM1210 | | | MURATA | GRM32ER61C476ME15L |
| 11 | 2 | C8, C9 | 1800 μ F | | 12.5x20mm | | 25 | CHEMI CON | EKZE250ELL182MK30S |
| 12 | 3 | C10, C24, C29 | 0.1 μ F | | SM0603 | | | | |
| 13 | 1 | C12 | 220nF | | SM0603 | | | | |
| 14 | 1 | C13 | 470nF | | SM0603 | | | | |
| 15 | 1 | C15 | 10nF | | SM0603 | | | | |
| 16 | 2 | C16, C20 | 6.8 μ F | | SM0805 | | | | |
| 17 | 1 | C17 | 220pF | | SM0603 | | | | |
| 18 | 1 | C18 | 470pF | | SM0603 | NPO/C0G | | | |
| 19 | 2 | C19, C20 | 220nF | | SM0603 | | | | |
| 20 | 1 | C21 | DNP | :220n | SM0603 | | | | |
| 21 | 1 | C23 | 220nF | | SM0805 | | 25 | | |
| 22 | 2 | C25, C28 | 1.2nF | | SM0603 | | | | |
| 23 | 1 | F1 | 0.5A | | FUSE | | | | TR5 |
| 24 | 1 | L1 | 330 μ F | | | | | COILCRAFT | MSS1278-334KLB |
| 25 | 1 | L2 | 390 μ F | | | | 500 | COILCRAFT | MSD1278-334KLB |
| 26 | 1 | L3 | 39 μ F | | | | 650 | PULSE | PA2050.393NL |
| 27 | 5 | P1, P2, P3, P4, P5 | TERMINAL | | | | | KEYSTONE | 1514-2 |
| 28 | 1 | Q0 | 1A | | DPAK | | | FAIRCHILD | FQD1N50TM |
| 29 | 1 | Q1 | 3.2A | | DPAK | | | INFINEON | IPD60R385CP |
| 30 | 2 | Q3, Q5 | BSS138 | | SOT23 | | | | |
| 31 | 3 | R1, R2, R6 | 1.0M | | SM1206 | 5% | | | |
| 32 | 2 | R3, R7 | 0 Ω | | RES-2W | 5% | | | |
| 33 | 1 | R4 | 100 Ω | | SM1206 | 5% | | | |
| 34 | 2 | R8, R9 | 100k Ω | | SM1206 | 1% | | | |
| 35 | 1 | R10 | 14.3k Ω | | SM0603 | 1% | | | |
| 36 | 1 | R11 | 100 Ω | | SM0603 | 5% | | | |
| 37 | 1 | R12 | 0.05 Ω | | SM2512 | 5% | | | |
| 38 | 1 | R13 | 10 Ω | | SM0805 | 5% | | | |
| 39 | 1 | R14 | 499 Ω | | SM1206 | 5% | | | |

TABLE 5. ISL6745ALEVAL3Z NON-ISOLATED LED ADAPTOR WITHOUT TRIAC DIMMING (Continued)

| NO. | QTY. | REFERENCE | VALUE | VALUE NO. | PACKAGE | TOL | VOLTAGE (V) | VENDOR | PART NO. |
|-----|------|------------------------------|----------|-----------|---------|-----|-------------|------------|--------------|
| 40 | 1 | R15 | 51.1Ω | | SM0805 | 5% | | | |
| 41 | 1 | R16 | DNP | | SM1206 | 5% | | | |
| 42 | 1 | R17 | 0.18Ω | | SM1206 | 1% | | | |
| 43 | 1 | R18 | 3.01MΩ | | SM0603 | 5% | | | |
| 44 | 1 | R19 | 2kΩ | | SM0603 | 5% | | | |
| 45 | 1 | R21 | 10kΩ | | SM0603 | 5% | | | |
| 46 | 1 | R22 | 1kΩ | | SM1206 | 5% | | | |
| 47 | 6 | R23, R24, R27, R28, R31, R32 | 10.0kΩ | | SM0603 | 1% | | | |
| 48 | 1 | R25 | 14.0kΩ | | SM0603 | 1% | | | |
| 49 | 1 | R26 | 30.1kΩ | | SM0603 | 1% | | | |
| 50 | 1 | R29 | 59.0kΩ | | SM0603 | 1% | | | |
| 51 | 1 | R32 | 150kΩ | | SM0603 | 5% | | | |
| 52 | 1 | R33 | 61.9kΩ | | SM0603 | 5% | | | |
| 53 | 1 | R34 | 196kΩ | | SM0603 | 1% | | | |
| 54 | 1 | R39 | 1.0kΩ | | SM0603 | 5% | | | |
| 55 | 1 | U1 | ISL6745A | | MSOP10 | | | INTERSIL | ISL6745AAU |
| 56 | 1 | U3 | EL5420 | | TSSOP14 | | | INTERSIL | EL5420CRZ |
| 57 | 1 | VR1 | 11V | | SOT23 | | | DIODES | BZX84C11 |
| 58 | 1 | VR2 | 24V | | SOT23 | | | VISHAY | MMBZ5252 |
| 59 | 1 | VR3 | 5.1V | | SOT23 | | | DIODES | BZX84B5V1LT1 |
| 60 | 1 | VR4 | DNP | | SOT23 | | | DIODES | BZX84C18 |
| 61 | 1 | Z1 | - | | - | | | LITTELFUSE | TMOV14R140E |

TABLE 6. ISL6745ALEVAL3Z NON-ISOLATED LED ADAPTOR WITH TRIAC DIMMING

| NO. | QTY. | REFERENCE | VALUE | VALUE NO. | PACKAGE | TOL | VOLTAGE (V) | VENDOR | PART NO. |
|-----|------|--------------------|----------------|-----------|------------------|---------|-------------|-----------|--------------------|
| 1 | 1 | CR1 | 2A | | BRIDGE RECTIFIER | | 400 | DIODES | 2W04G |
| 2 | 1 | CR2 | 3A | | SMC | | 600 | DIODES | RS3J-E3 |
| 3 | 1 | CR3 | BAT54C | | SOT23 | | | DIODES | |
| 4 | 1 | CR4 | BAT54 | | SOT23 | | | DIODES | |
| 5 | 2 | C1, C2 | 0.1 μ F | | X2-CAP | | 250 | PANASONIC | ECQU2A 104ML |
| 6 | 1 | C3 | 22nF | | SM1812 | | 250 | TDK | C453C0G2E223J |
| 7 | 1 | C4 | 47nF | | SM1812 | | 250 | TDK | C453C0G2E223J |
| 8 | 1 | C5 | DNP | | SM1210 | | 100 | MURATA | |
| 9 | 1 | C6 | 2.2 μ F | | SM0603 | | | MURATA | GRM31CR71H225K |
| 10 | 2 | C7, C27 | 47 μ F | | SM1210 | | | MURATA | GRM32ER61C476ME15L |
| 11 | 2 | C8, C9 | 1800 μ F | | 12.5x20mm | | 25 | CHEMI CON | EKZE250ELL182MK30S |
| 12 | 3 | C10, C24, C29 | 0.1 μ F | | SM0603 | | | | |
| 13 | 1 | C12 | 220nF | | SM0603 | | | | |
| 14 | 1 | C13 | 470nF | | SM0603 | | | | |
| 15 | 1 | C15 | 10nF | | SM0603 | | | | |
| 16 | 2 | C16, C20 | 6.8 μ F | | SM0805 | | | | |
| 17 | 1 | C17 | 220pF | | SM0603 | | | | |
| 18 | 1 | C18 | 470pF | | SM0603 | NPO/COG | | | |
| 19 | 2 | C19, C20 | 220nF | | SM0603 | | | | |
| 20 | 1 | C21 | DNP | :220n | SM0603 | | | | |
| 21 | 1 | C23 | 220nF | | SM0805 | | 25 | | |
| 22 | 2 | C25, C28 | 1.2nF | | SM0603 | | | | |
| 23 | 1 | F1 | 0.5A | | FUSE | | | | TR5 |
| 24 | 1 | L1 | 330 μ H | | | | | COILCRAFT | MSS1278-334KLB |
| 25 | 1 | L2 | 390 μ H | | | | 500 | COILCRAFT | MSD1278-334KLB |
| 26 | 1 | L3 | 39 μ H | | | | 650 | PULSE | PA2050.393NL |
| 27 | 5 | P1, P2, P3, P4, P5 | TERMINAL | | | | | KEYSTONE | 1514-2 |
| 28 | 1 | Q0 | 1A | | DPAK | | | FAIRCHILD | FQD1N50TM |
| 29 | 1 | Q1 | 3.2A | | DPAK | | | INFINEON | IPD60R385CP |
| 30 | 2 | Q3, Q5 | BSS138 | | SOT23 | | | | |
| 31 | 3 | R1, R2, R6 | 1.0M Ω | | SM1206 | 5% | | | |
| 32 | 2 | R3, R7 | 36 Ω | | RES-2W | 5% | | | |
| 33 | 1 | R4 | 0 Ω | | SM1206 | 5% | | | |
| 34 | 2 | R8, R9 | 100k Ω | | SM1206 | 1% | | | |
| 35 | 1 | R10 | 14.3k Ω | | SM0603 | 1% | | | |
| 36 | 1 | R11 | 100 Ω | | SM0603 | 5% | | | |
| 37 | 1 | R12 | 0.05 Ω | | SM2512 | 5% | | | |
| 38 | 1 | R13 | 10 Ω | | SM0805 | 5% | | | |
| 39 | 1 | R14 | 499 Ω | | SM1206 | 5% | | | |

TABLE 6. ISL6745ALEVAL3Z NON-ISOLATED LED ADAPTOR WITH TRIAC DIMMING (Continued)

| NO. | QTY. | REFERENCE | VALUE | VALUE NO. | PACKAGE | TOL | VOLTAGE (V) | VENDOR | PART NO. |
|-----|------|------------------------------------|----------|-----------|---------|-----|-------------|------------|--------------|
| 40 | 1 | R15 | 51.1Ω | | SM0805 | 5% | | | |
| 41 | 1 | R16 | DNP | | SM1206 | 5% | | | |
| 42 | 1 | R17 | 0.18Ω | | SM1206 | 1% | | | |
| 43 | 1 | R18 | 3.01MΩ | | SM0603 | 5% | | | |
| 44 | 1 | R19 | 2kΩ | | SM0603 | 5% | | | |
| 45 | 1 | R21 | 10kΩ | | SM0603 | 5% | | | |
| 46 | 1 | R22 | 1kΩ | | SM1206 | 5% | | | |
| 47 | 6 | R23, R24, R27, R28, R31, R32 | 10.0kΩ | | SM0603 | 1% | | | |
| 48 | 1 | R25 | 14.0kΩ | | SM0603 | 1% | | | |
| 49 | 1 | R26 | 30.1kΩ | | SM0603 | 1% | | | |
| 50 | 1 | R29 | 59.0kΩ | | SM0603 | 1% | | | |
| 51 | 1 | R32 | 150kΩ | | SM0603 | 5% | | | |
| 52 | 1 | R33 | 61.9kΩ | | SM0603 | 5% | | | |
| 53 | 1 | R34 | 196kΩ | | SM0603 | 1% | | | |
| 54 | 1 | R39 | 1.0kΩ | | SM0603 | 5% | | | |
| 55 | 1 | U1 | ISL6745A | | MSOP10 | | | INTERSIL | ISL6745AAU |
| 56 | 1 | U3 | EL5420 | | TSSOP14 | | | INTERSIL | EL5420CRZ |
| 57 | 1 | VR1 | 11V | | SOT23 | | | DIODES | BZX84C11 |
| 58 | 1 | VR2 | 24V | | SOT23 | | | VISHAY | MMBZ5252 |
| 59 | 1 | VR3 | 5.1V | | SOT23 | | | DIODES | BZX84B5V1LT1 |
| 60 | 1 | VR4 | DNP | | SOT23 | | | DIODES | BZX84C18 |
| 61 | 1 | Z1 | - | | - | | | LITTELFUSE | TMOV14R140E |

Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.
2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.
3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.
5. Renesas Electronics products are classified according to the following two quality grades: "Standard" and "High Quality". The intended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below.
"Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; industrial robots; etc.
"High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control (traffic lights); large-scale communication equipment; key financial terminal systems; safety control equipment; etc.
Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implantations; etc.), or may cause serious property damage (space system; undersea repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user's manual or other Renesas Electronics document.
6. When using Renesas Electronics products, refer to the latest product information (data sheets, user's manuals, application notes, "General Notes for Handling and Using Semiconductor Devices" in the reliability handbook, etc.), and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.
7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public in the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.
8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.
10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.
11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.
(Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.
(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

(Rev.4.0-1 November 2017)



SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

Renesas Electronics America Inc.
1001 Murphy Ranch Road, Milpitas, CA 95035, U.S.A.
Tel: +1-408-432-8888, Fax: +1-408-434-5351

Renesas Electronics Canada Limited
9251 Yonge Street, Suite 8309 Richmond Hill, Ontario Canada L4C 9T3
Tel: +1-905-237-2004

Renesas Electronics Europe Limited
Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K.
Tel: +44-1628-651-700, Fax: +44-1628-651-804

Renesas Electronics Europe GmbH
Arcadiastrasse 10, 40472 Düsseldorf, Germany
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

Renesas Electronics (China) Co., Ltd.
Room 1709 Quantum Plaza, No.27 ZhichunLu, Haidian District, Beijing, 100191 P. R. China
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

Renesas Electronics (Shanghai) Co., Ltd.
Unit 301, Tower A, Central Towers, 555 Langao Road, Putuo District, Shanghai, 200333 P. R. China
Tel: +86-21-2226-0888, Fax: +86-21-2226-0999

Renesas Electronics Hong Kong Limited
Unit 1601-1611, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong
Tel: +852-2265-6688, Fax: +852-2886-9022

Renesas Electronics Taiwan Co., Ltd.
13F, No. 363, Fu Shing North Road, Taipei 10543, Taiwan
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

Renesas Electronics Singapore Pte. Ltd.
80 Bendemeer Road, Unit #06-02 Hyflux Innovation Centre, Singapore 339949
Tel: +65-6213-0200, Fax: +65-6213-0300

Renesas Electronics Malaysia Sdn.Bhd.
Unit 1207, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

Renesas Electronics India Pvt. Ltd.
No.777C, 100 Feet Road, HAL 2nd Stage, Indiranagar, Bangalore 560 038, India
Tel: +91-80-67208700, Fax: +91-80-67208777

Renesas Electronics Korea Co., Ltd.
17F, KAMCO Yangjae Tower, 262, Gangnam-daero, Gangnam-gu, Seoul, 06265 Korea
Tel: +82-2-558-3737, Fax: +82-2-558-5338